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PHYSICAL REASONS OF POLYESTHER RESIN SURFACING SYSTEMS FAILURES

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INTRODUCTION

Apart from successful applications of PE resin floorings and surfacings /cast floorings, screeds, GRP, PC/ we often encounter failures of these systems at various ages. Their number includes dense micro- or macro-cracks of surface /crackelling/, creasing, rare but wide cracks passing through the whole system depth and accompanied with bowl-like lifting of adges, lifting of adges near expansion joints and all ends, blisters of various diameters /from mm to tens of cm/, nonhardening of some layer or their subsequent softening, which results in the punching of holes in the flooring or its separation from its base or separation of individual layers. Some failures are due to structural system used /and do not depend much on the type of binder/, others are due to the properties of PE resin used and are based on insuitable design or technological defects.

The factors causing failures can be classified /although they often combine/ - with some risk of simplification - into
a/physical /mechanical, structural/ factors,
b/chemical factors,
c/microbiological factors.
Let us consider only the physical factors.

The flooring as such is a composite system /structural, non-homogeneous, porous, with merkedly different phases/, being also a part of a stratified composite of the whole floor structure. The structural and mechanical assessment of the whole floor shows that the influence of the type of resin used in the flooring material is obviously of minor importance.

BINDER SHRINKAGE

The polymerization of the PE resin is an exothermic process /some 60 cal/g per 2 hours/ and is accompanied with shrinkage by 5 - 8% of volume. The presence of filler reduces the shrinkage considerably. The shrinkage is quickest in the first phase, until the gel stage is reached; however, it continues for a long time afterwards, sometimes as long as 4 years. In the structure of the hardening layer tensile stresses arise in the matrix /resin/, compressive stresses in the filler, and shearing stresses in their joints as well as in the joints with the adjoining layer. Normal stresses attain 2.5 - 3.0, but also as much as 30 MPa, shearing stresses 15 - 30% of normal stresses. If, during the process of hardening, the stress in some place exceeds the momentary strength of the material, microfailures of structure originate limiting further usability of the flooring; in some cases even a macrofailure can occur /separation of flooring from its base, origin of cracks/. The extent of failure depends on the speed of hardening, selection of binder components, thickness of binder between filler particles, overall layer thickness, porosity of the system /in porous systems the shrinkage stress is 15% lower/, relation between shrinkage and stress relaxation in every moment of hardening, etc.

To prevent shrinkage failures of PE resin systems it is necessary to ensure that
a/the matrix layer both in the flooring structure and in the whole floor system be as thin as possible /PC with binder /filler ratio of 1:7-1:12 by weight, screeds and cast floorings up to 2 mm of thickness/,

b/the main shrinkage process /approx.80%/ be as long as possible /at least 24 hours/.

EFFECTS OF TEMPERATURE

The coefficient of thermal expansivity of neat PE resin is 6-11.10^{-5} mm/°C, i.e. many times higher or even of a higher order than that of other materials present. Any change of temperature from the "birth temperature" results in the origin of high internal stresses within flooring structure /in PC, for example, a temperature difference of 10°C is accompanies by a 0.216% volume change, producing in the binder and in the filler normal stresses of the order of 5 MPa and shear stresses of 0.7-1.3 MPa/ and within the composite system of the whole floor /the thinner the flooring, the more speedily it reacts to temperature changes and the more disadvantageous it is, which is contrary to the requirement with regard to shrinkage/. A reduction of temperature below the "birth temperature" is more disadvantageous than its increase /the effects are added to those of shrinkage; moreover, rheological properties deteriorate with decreasing temperature/. Shearing stresses in the joints between layers depend on temperature changes, difference of thermal expansivity coefficients, moduli of elasticity and deformation, ultimate strain, stress relaxation and creep of the layers. The development of shear stresses along the depth of flooring /and base/ is not linear; from the maximum in the vicinity of the contact zone it decreases parabolically towards the distant ends of layers. In the case of imperfect or non-existing bond of layers there originate, at the boundaries /similarly as at the ends and at expansion joints/, the places of a high concentration of horizontal shear stresses /as much as 5 times as high as their mean values/. In the course of time the effects of temperature changes become more dangerous with regard to the deterioration of rheological properties.

To prevent failures due to temperature changes it is necessary to ensure that the
a/binder contents in the flooring be minimum,
b/hardening process take place at the lowest temperature possible 10-20°C/,
c/origin of discontinuity between the flooring and its base be prevented, the flooring expansion joints be limited only to the expansion joints of the structure, and all ends be designed specially.

COMPOSITE BEHAVIOUR

With regard to non-homogeneity /different physical properties/ of the flooring along its depth the shrinkage and temperature changes produce the composite behaviour of the flooring, i.e. the mutual mechanical stressing of the layers followed by the bending of the system similarly as is the case of e.g. a bimetallic cell. Increasing temperature results in concave bending of the flooring, reduction in convex lifting of edges. The failures due to this reason occur, as a rule, first at the contact with the base /usually cement concrete/. The bond, however good /e.g. produced by priming/ cannot prevent the failure, if the system has not been well designed. The only way to successful design is
a/limiting the differences between individual layers /minimum amount of binder, special softened binders, etc./,
b/design of the flooring so as to make it symetric with regard to the middle surface; e.g. if the surfacing on top of PC consists in little filled resin, similar layer /of analogous composition and thickness/ should be placed also on the other side as contact layer.

MECHANICAL PROPERTIES

Concentrated loading of the flooring results in transverse stresses which can considerably influence its use. Decisive are moduli of elasticity, moduli of deformation and Poisson coefficients of adjoining layers. A detailed analysis has shown that for flooring thickness of 2 cm and = 0.30 a still permissible horizontal shear stress of 1 MPa in the joint is produces by a static load of 5300 N /i.e. in terms of dynamic effects a working load of 2600 - 1000 N/. For flooring thickness of 5 mm and = 0.40 /screed/ identical stress is produced by a static load of 250 N. The thinner the flooring the more desirable higher strength of base: for flooring thickness of the order of mm it varies between 20 - 25 MPa, for that of the order of cm between 15-20 MPa. An improvement may be attained by an increase of flooring /base bond by means of increasing the specific contact surface /sand blasting etc./

Indispensable properties of the flooring are also its strength, abrasion resistance, hardness, etc. The systems used are satisfactory in this respect, as a rule.

STRUCTURAL EFFECTS

The structure of the flooring is influenced by its composition /ratio and properties of components/, working and curing.

The filler should consist of three gradings at least /incl. microfiller/ and should be gap-graded, with minimum void volume, dry, clean and chemically resistant. The binder must have a suitable viscosity /to suit the method of working/, uninfluenced by diluters /incl. reactive/. In PE systems the mixing ratio of all components, the effectiveness of mixing and homogeneity of the mix are particularly important. During mixing airentrainment should be prevented. An ideal PC mix is closely below the continuous porosity boundary after hardening /1:6-1:11 by weight/. Also the conditions of hardening /temperature, moisture/ are of decisive importance.

MOISTURE CONTENT OF RAW MATERIALS, BASE AND ENVIRONMENT

PE resins are very sensitive to moisture: the smallest quantity of moisture inhibits and modifies polymerization reactions. The filler, therefore, must be pre-dried and have a moisture content of less than 0.3% by weight.

Hardening is inhibited also by air oxygen, particularly if the air is moist. Insuitably organized polymerization process may entirely prevent the hardening, particularly of the top layer.

Base humidity /stationary-induced, or dynamic-from the atmosphere or subbase/, which can be present in fluid or vapour form, plays a decisive role in the hardening process and influences decisively also the life expectance of the flooring after hardening. Fluid humidity, apart from unfavourable chemical effect, can impair the material also physically, particularly by its cleavage effect at phase boundaries within the structure /as well as by capillary forces/ and particularly at the boundaries of individual layers of the composite system. Detrimental effect of negative temperature in such a case is obvious.

The effect of moisture in the floor system is increased by simultaneous existence of negative temperature gradient /i.e. temperature sinking from the lower towards the upper surface/. As the flooring can be penetrated by vapours in the quantity differing by several orders /below 0.0001 kg/sq.m.h/, from that penetrating through other layers of the floor, the temperature gradient results in a considerable overpressure originating below the flooring /a gradient of 25°C produces an overpressure of some 20 kPa/. The

The diffusion of moisture from the whole floor system below the flooring results in condensation, penetration of vapour and liquid into lower flooring strata, physical and chemical disturbance of its structure, cleavage, deformation of top layer /blisters/ or its breakage /by overpressure of mechanical stresses/, separation of flooring from the base. The effect of chemical corrosion, comprising oxidation and hydrolysis giving rise to a number of further complex products /benzaldehyde, formaldehyde, fenylethyleneglycol, etc./ depending on the type of PE resin, quantity of monomer /styrene/, type of polymerization system, organization of polymerization and environment.

For practical purposed sufficiently dry floor system should not contain more moisture than 2.5% by weight, if the difference of vapour tension on the surfaces exceeds 10 mm Hg /1.33 kPa/;if below 10 mm Hg, then 3.5% by weight. In some cases /e.g.with regard to chemical effects/ the requirement may be even lower. As the extent of failure due to moisture depends on the absolute quantity of free water in the system, the most satisfactory solution in a number of cases /although somewhat more costly/ is the separation of the concrete base /some 4 cm in depth/from other layers of the floor system by a vapour barier with a diffusion resistance comparable to that of the flooring /e.g. standard DPC in asphaltbed/. To prevent capillary action the base should be always separated from lower layers by a discontinuity layer, e.g. dry asphalt cardboard. The atmospheric inhibition can be reduced e.g. by parafinic admixtures.

To prvent unfavourable effect of moisture it is necessary particularly:

a/to select a catalytic system and type of resin suitable with regard to chemical resistance and speed of hardening; in case of higher alkalinity of more suitable resin /e.g. eposy/ should be used at least for priming;

b/to use pre-dried filler only and eliminate all components inhibiting polymerization /in pigments, white, filler/, ensure perfect batching and mixing of all components;

c/to ensure drying of the base and all floor layers above vapour barier /2.5% or 3.5% moisture content according to assumed temperature gradient/; and relative air humidity below 60% for execution.

AGEING

Elasticity and yield of PE floorings is reduced by time, the resin becomes brittle, particularly if exposed to UV radiation. The unfavourable effect of UV radiation is markedly reduced in the systems with aggregate filler /approx. 1:8 by weight/. In exterior applications, therefore, only such systems may be used /without top layer of non-filled resin/. Screeds and cast floorings cannot be used.

BASE PREPARATION

The importance of proper base preparation cannot be overaccentuated. Poor quality top layer of concrete /consisting of light weight cement and filler particles/ must be removed /at least by crushing/ and the surface rid of dust /by exhaust/. Better effect is attained by sand blasting which increases specific surface and improves the effect of priming. Deep penetration of priming material is enabled by slowly evaporating diluters /not by acetone, e.g./

CONCLUSION

PE resin floorings, when well mixed, placed and polymerized, are very good, economic even when heavily trafficked, and long lasting /except in moist, alkali environment/.Their execution, however, requires strict adherence to prescribed technology, modified for every particular case. Deviations from this technology result in various failures, reducing the service value of the flooring. Considerable requirements imposed on technological discipline have resulted in an ever increasing replacement of in-situ applications with the precasting of parts with PE binders in workshops.